Moving Threat: Attention and Distance Change Interact in Threat Responding

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Abstract

Defensive reactions need to be quick and appropriate to ensure survival. So, it is crucial that threats trigger immediate action upon detection, even in the absence of awareness. Also, the form of such action should be appropriate to the imminence of the threat. Thus, attention should be guided by signals of increasing threat imminence. We examined whether subliminally presented threat stimuli provoke automatic avoidance tendencies and whether threat cues' distance change and threat potential determine attention allocation. Following fear conditioning, participants performed an approach-avoidance task with subliminally presented conditioned threat and safety stimuli and an attentional bias task with approaching versus distancing signals of threat and safety. Pre-attentive processing of threat cues resulted in approach rather than avoidance tendencies; attention was captured preferentially by signals of increasing threat imminence. The results support the importance of threat imminence and extend findings of previous research on pre-attentive influences on defensive responding.

Keywords: attention, avoidance tendencies, pre-attentive processing, fear conditioning, threat imminence

Moving threat: Attention and distance change interact in threat responding

Reacting quickly and appropriately to threat is of utmost importance for survival. Processing threats before they become available to consciousness can offer an evolutionary advantage by preparing an organism for defensive responding (e.g., Öhman & Soares, 1993; Öhman, 2013). Research has shown that pre-attentive threat detection results in a variety of automatic fear responses (e.g., Beaver, Mogg, & Bradley, 2005), however, it is not clear whether it also primes defensive action (i.e., an avoidant action tendency). Once a threat signal enters awareness, if not before, a process of response selection can start to determine the appropriate form of avoidance (Fanselow & Lester, 1988). Threat imminence appraisal involves the evaluation of the spatial, as well as the psychological, distance between the threat and the organism and influences response selection (Fanselow & Lester, 1988; Lang, Bradley, & Cuthbert, 1997; Lang & Bradley, 2013). Thus, both activation of avoidance tendencies upon pre-attentive processing of threat and preferential attention to changes in perceived threat imminence should be evolutionary advantageous. Here, we examine these two processes.

Pre-attentive processing of threat activates the defensive motivational network (Öhman & Soares, 1993). This activation can be inferred from the observation of defensive reactions in response to a neutral stimulus (e.g., a neutral face; a mask), when it follows a subliminally presented threat stimulus (e.g., an angry face, presented for 14 to 33 ms and previously associated with shock; Mogg & Bradley, 1999; Olsson & Phelps, 2004). Such masked presentation of threat stimuli results in increased skin conductance responses (e.g., Esteves, Dimberg, & Öhman, 1994; Flykt, Esteves, & Öhman, 2007; Morris, Öhman, & Dolan, 1998; Öhman & Soares, 1993; Olsson & Phelps, 2004), amygdala activity (Morris et al., 1998; Whalen et al., 1998), attention (Beaver et al., 2005; Mogg & Bradley, 1999, 2002) and facial mimicry (Dimberg, Thunberg, & Elmehed, 2000), without participants being consciously aware of the threat stimulus. However, it is yet unclear whether pre-attentive processing can also provoke avoidance.

Overt avoidance behavior can be thought of as resulting from the interaction between automatic reflex-like avoidance tendencies and effortful behavioral control processes (Krypotos, Effting, Kindt, & Beckers, 2015). Avoidance tendencies refer to the priming of distance-increasing responses upon the presentation of a threat stimulus. For instance, individuals are faster to increase the distance (avoid) between a symbolic manikin and a threat signal and decrease the distance (approach) between the same manikin and a safety signal than the other way around in an approach-avoidance reaction time task (AAT; Krypotos, Effting, Arnaudova, Kindt, & Beckers, 2014). Avoidance tendencies operate automatically (Krieglmeyer, De Houwer, & Deutsch, 2013) and can be observed even when participants react to threat-irrelevant aspects of the stimuli (Krypotos et al., 2014). Thus, it seems feasible that these distance-regulating tendencies would also be activated by threat signals that are presented subliminally. Indeed, Graham (1992) suggested that elemental properties of a stimulus, which can be processed pre-attentively, provoke various reflexes (e.g. orienting reflex, SCR); avoidance tendencies might arguably be among them (Öhman, 2013).

Previous research has shown that the concept of avoidance is activated by conscious priming with threatening out-group cues (Wyer, 2010) and that this priming also results in increased seating distance from a confederate in an unrelated task (Wyer, Calvini, Nash, & Miles, 2010). Further, one experiment showed that subliminal processing of images of stereotypically dangerous individuals (e.g., a man wearing a hoodie) resulted in participants sitting further away from a confederate (Wyer & Calvini, 2011). Taken together, these findings offer support to the idea that both conscious and subliminal threat priming can increase overt avoidance behavior in subsequent tasks, but whether this occurs through activating motivated distance-regulation tendencies to the priming cue itself remains unclear.

Spatial distance change between the threat and the organism is one of the main factors determining threat imminence (Fanselow & Lester, 1988). Threat imminence critically regulates how activation of the defensive system is translated into a specific behavioral response in animals (Fanselow & Lester, 1988) and a recent study showed that threat imminence increases are associated with physiological responses indicative of action preparation in humans as well (Löw, Weymar, & Hamm, 2015). Attention should be similarly devoted specifically to increases in threat imminence, because this would allow for faster selection of the appropriate defensive response.

To our knowledge, the effect of threat imminence on attention, however, has not yet been directly examined within attentional bias tasks (but see Löw et al., 2015 for psychophysiological responses related to attention allocation to threat imminence increases). In such tasks, static threats generally capture attention (Koster, Crombez, Van Damme, Verschuere, & De Houwer, 2005; Koster, Crombez, Verschuere, & De Houwer, 2004; Van Damme, Crombez, Hermans, Koster, & Eccleston, 2006). An important open question is whether the degree of attention allocation to a threat signal is modulated by changes in its spatial distance. From a threat imminence perspective, paying attention to increases in threat imminence should be of evolutionary advantage. Increases in threat imminence might occur both when the distance between a threat signal and the organism decreases and when the distance between a safety signal and the organism increases.

When the distance between an object and the organism decreases, some sort of interaction between the two becomes likely. Consequently, it might be advantageous to attend closely to distance decreases between any object and the individual, regardless of threat potential. It has been previously found that individuals show stronger SCR when perceiving a movement towards themselves than when perceiving an away-movement (Bernstein, Taylor, Austen, Nathanson, & Scarpelli, 1971), are faster in categorizing a toward-movement than an away-movement (Adams, Ambady, Macrae, & Kleck, 2006; van Peer, Rotteveel, Spinhoven, Tollenaar, & Roelofs, 2009, Experiment 4), and have stronger fear-potentiated startle reactions in the presence of proximal as compared to distal social stimuli (Åhs, Dunsmoor, Zielinski, & LaBar, 2014, Experiment 1). Other psychophysiological responses (e.g., startle, heart rate) have also been associated with the approach of emotional stimuli (Löw, Lang, Smith, & Bradley, 2008). Together, these findings point to the great importance of spatial distance (change).

Interestingly, in a number of studies, exactly the opposite of what would be predicted by the threat imminence account has been observed. Individuals were faster to categorize the valence of negative stimuli (e.g., words; angry faces) when moving away and the valence of positive stimuli (e.g., words; happy faces) when moving towards them (Neumann & Strack, 2000, Experiments 2-3; van Peer et al., 2009, Experiments 1-3). If such valence congruency (responding to movements congruent with the stimulus valence) is a critical factor in guiding attention, the prediction for the effect of threat movement on attention allocation would be exactly the opposite of that from a threat imminence perspective.

In the present experiment, we evaluated whether subliminally presented threat cues can trigger distance-regulating action tendencies, and whether changes in spatial distance of threat versus safety signals in turn guide the automatic allocation of attention. In a fear-conditioning paradigm, we repeatedly paired a picture of one neutral face (conditioned stimulus, CS+) with an aversive outcome (shock; unconditioned stimulus, US) to establish fear for the CS+; another neutral face was never paired with the shock (CS-) and served as a safety cue. We used a fear conditioning procedure in order to have full counterbalancing control over the threat (CS+) and safety (CS-) signals, so that perceptual differences between the stimuli could not confound our results. We then tested whether the subliminal presentation of the CS+ would result in conditioned avoidance tendencies in an AAT. After confirming that participants were unable to detect the stimuli presented during the AAT, we subsequently examined the joint effects of threat potential and distance change on the allocation of attention in an attentional bias task (dot probe task, DPT). If mere threat potential is important, participants should show an attentional bias to the CS+ only, as in Koster and colleagues (2004), for example. On the other hand, if only distance change elicits preferential processing, attention should be allocated preferentially to approaching rather than withdrawing stimuli. If valence congruency is what primarily guides attention, attentional bias should be observed towards CS+ stimuli moving away and CS- stimuli moving toward the participant. Last but not least, according to a threat imminence account, one should expect preferential attention allocation to approaching CS+ and withdrawing CS- pictures.

Methods

Participants

Participants were recruited online and pre-screened for the following exclusion criteria over the phone: 1) (history of) psychiatric disorders; 2) epilepsy; 3) heart condition; 4) current pregnancy; and 5) use of medications that can influence attention, memory, or reaction time. We collected data from a final sample of 40 participants. With an α-level of .05, this sample size was determined to yield a power of over .90 for detecting a conditioned avoidance tendency of the size reported in Krypotos et al. (2014; $.20 < \eta_p^2 < .25$), while allowing full counterbalancing of instructions. One participant did not complete the study, another one was excluded due to technical problems and three were excluded for having used illegal substances in the last 24 hours before experiment participation[1]. These participants were immediately replaced. The final sample (*n* = 40; 10 male) had a mean age of 29.08 (*SD* = 14.79, range = 18 – 68).

Materials

Images of two neutral male faces from the Karolinska Directed Emotional Faces (KDEF; Lundqvist, Flykt, & Öhman, 1998) set were used as conditioned stimuli (AM04NES and AM29NES). Faces have been commonly used as stimuli in research of pre-attentive processing to conditioned stimuli (e.g., Esteves et al., 1994; Morris et al., 1998; Olsson & Phelps, 2004). The images used here were chosen because they had previously been used as neutral stimuli (Golkar & Öhman, 2012). The assignment of the images (83 mm x 110 mm) to CS+ and CS- was counterbalanced across participants.

For the AAT, the images were reduced in size (35% of CS size) and superimposed on frames with a white background of either horizontal (98 mm × 53 mm) or vertical (53 mm × 98 mm) orientation for use as stimulus pictures. The mask image was created by scrambling two other neutral male faces from the KDEF set (AM02NES and AM06NES) and was prepared similarly to stimulus pictures for use in the AAT.

[1] Technically, some of the used substances are not illegal in the Netherlands (i.e., marihuana).

The US was a 2-ms electric stimulus, delivered by a DS7A Constant Current Stimulator (Digitimer Ltd., Hertfordshire, UK) to the dorsal side of the wrist of the participant's non-dominant hand (Effting & Kindt, 2007), through two Ag electrodes covered with conductive gel (Signagel, Parker, Fairfield, NJ). The strength of the US was established for each participant individually through a work-up procedure (Orr et al., 2000) to an uncomfortable, but non-painful level.

Questionnaires

US expectancies were measured on an 11-point Likert scale (-5, certainly not expecting an electric stimulus; 0, uncertain; 5, certainly expecting an electric stimulus). Upon each CS presentation, participants had 5.5 s to move a cursor on the scale, presented at the bottom of the computer screen. The cursor was located at zero at the beginning of each trial. Participants could confirm their response with a mouse click (otherwise, the last position of the cursor was recorded).

Pleasantness of stimuli (CSs, US, and mask) was recorded on a similar 11-point Likert scale ranging from -5 (unpleasant) to 5 (pleasant). Participants also evaluated US intensity (light, moderate, intense, enormous, unbearable) and startlingness (not, light, moderate, strong, very strong).

General negative affective states were assessed using the Depression Anxiety Stress Scales (DASS; Lovibond & Lovibond, 1995; Dutch translation by de Beurs, Van Dyck, Marquenie, Lange, & Blonk, 2001). *Anxiety sensitivity,* or fear of experiencing arousal, was measured with the Anxiety Sensitivity Index (Reiss, Peterson, Gursky, & McNally, 1986; Dutch tranlsation by Vujanovic, Arrindell, Bernstein, Norton, & Zvolensky, 2007). Those questionnaires were included for exploratory purposes; their results are not reported here.

Procedure

After receiving information about the experiment and giving informed consent, participants sat in front of the experimental computer and the electric stimulation electrodes were attached to determine US intensity. The acquisition procedure started immediately thereafter.

Verbal and on-screen instructions informed participants that one face would be always followed by the US, while the other one would never be, and that they had to report their US expectancies upon each stimulus presentation. Participants received 8 CS+ and 8 CS- trials, each trial lasting 8 s. At the 7.5th second of each CS+ presentation, the US occurred. Acquisition order was randomized with the restriction that no more than two consecutive trials of the same type could occur. The inter-trial intervals (ITI), during which an inactive US expectancy scale was presented on the screen, had an average duration of 20 s. This phase ended with a three-minute pause.

Electric stimulation electrodes were removed before the beginning of the AAT. Instructions informed participants that in this task they had to move a small stick-figure manikin towards or away from pictures with a vertical or horizontal orientation, respectively (one block of trials with each type of instructions; order of instructions counterbalanced across participants). Speed and accuracy were emphasized.

The AAT consisted of two blocks of four practice trials and 16 target trials, which were semi-randomized, so that no more than two consecutive trials of the same type could occur, similarly to Krypotos et al. (2014). Each AAT trial was set up as follows. First, the manikin appeared centered to the bottom or top half of the screen. 1500 ms later, a CS stimulus picture was presented centered to the opposite side of the screen for 33 ms (two multiples of the 16.5-ms computer screen refresh rate;

Olsson & Phelps, 2004) to be immediately replaced by a mask with the same orientation as the CS stimulus picture. Participants could then press a button (B marked as 🡇 or Y marked as 🡅) and initiate the manikin's movement. The RT for the button press was recoded. Depending on the response, the manikin moved toward or away from the stimulus picture for 2000 ms. When the manikin reached its final position, it remained there for 500 ms. In the case of an incorrect trial, a red cross appeared for 500 ms at the starting position of the manikin. An ITI of 2000 ms followed, during which the screen remained blank. The next trial started immediately afterwards.

Short stimulus duration and backward masking in themselves do not rule out that stimuli are consciously detected. For instance, masked fearful faces have been shown to be detectable at presentation durations as short as 33 ms (Pessoa, Japee, & Ungerleider, 2005). We therefore tested participants' ability to detect the stimuli under the presentation conditions used for the AAT in a recognition task. Before that task, participants were informed that during the AAT, they had been briefly presented with images of one of two faces on every trial, which they might have missed. Participants were then instructed that they would again see the two faces trial-by-trial, masked in the same way, and that their task now was to try to recognize which face they were presented with. Trials of this forced-choice recognition task were set up similarly to the AAT, but instead of the manikin, the two CS images were presented next to each other, separated by 6 cm. Participants could press a button (A marked as <Left> and L marked as <Right>) to indicate the location of the face they believed they were presented with on the other half of the screen. No feedback was given during this task and participants received the same 40 practice and target trials in the same order as in the AAT. This recognition task was modeled after Golkar and Öhman (2012).

A modified dot-probe task (DPT) followed to measure attentional bias. It contained one practice block of 12 trials and two blocks of 2 buffer trials and 64 target trials. Every trial started with a fixation point presented in the middle of the screen for 500 ms. Then, two pictures simultaneously appeared on the screen for 500 ms. Upon their disappearance, a visual probe (🡅) was presented centered to the location of one of the two pictures. Participants reported the location of this probe with a button press. RT was recorded. During practice and buffer trials empty white pictures were presented, while during target trials CS images were presented.

In order to create a perception of movement during target trials, we consecutively presented the CS images in different sizes: from small to large to create the impression of approach (toward movement) and from large to small to create the impression of withdrawal (away movement). Medium CS images had the same size as those used in the acquisition phase, while small and large CS images were 33% smaller and 33% larger, respectively. There were four possible movement combinations: both CSs moving simultaneously toward or away from the participant and one CS (either CS+ or CS-) moving toward while the other CS (either CS- or CS+) was moving away from the participant. Trials were semi-randomized so that the same CS or the probe could not occur on the same location (left or right) consecutively more than three times and that the same movement combination could not be presented consecutively more than two times.

The experiment concluded with an assessment of participants' contingency awareness and the collection of CS pleasantness and US ratings. Participants also filled in the computerized DASS and ASI. Further, participants reported whether they found the mask to be more similar to one of the faces or had no idea to which face the mask was more similar. Finally, demographic information was collected.

Data Analysis

Acquisition data were analyzed by calculating the mean US expectancy for each CS across all trials and entering Stimulus as a within-subject variable in a repeated-measures Analysis of Variance (ANOVA). CS pleasantness ratings were analyzed in a similar manner. To ascertain the subliminal nature of stimulus processing during the AAT, the data from the forced-choice recognition test were compared to chance performance using one-sample t-tests, supplemented with a receiver operating characteristic (ROC) analysis (Area Under the Curve, AUC; Pessoa et al., 2005; Pessoa, 2005; Szczepanowski & Pessoa, 2007).

For the main analyses of interest, only target AAT and DPT trials were analyzed. Further, we removed all trials with incorrect responses and trials with long RTs (RTs longer than 3000 ms for the AAT, in line with Krypotos et al., 2014, and RTs longer than 1000 ms for the DPT, in line with Koster et al., 2005). Thus, we removed 78 trials from the AAT (6.09% of all trials) and 76 trials from the DPT (1.48% of all trials). We then calculated Median RTs (RTmd) per stimulus (CS+ or CS-) and AAT response (approach or avoid) or DPT movement (toward or away) combination. A repeated-measures ANOVA was conducted with Stimulus and AAT Response or DPT Movement as within-subject variables. The results of all ANOVAs were Greenhouse-Geisser corrected whenever the assumption of sphericity was violated.

Results

US evaluation

The US was evaluated as unpleasant (*M* = -2.46, *SD* = 2.29), intense (*M* = 2.98, *SD* = 0.53), and startling (*M* = 3.17, *SD* = 1.06).

Acquisition

Overall, fear acquisition was successful, as indicated by higher US expectancy ratings for the CS+ (*M* = 3.82, *SD* = 0.81) than the CS- (*M* = -3.86, *SD* = 0.85), $F(1, 39) = 975.13$, $p < .001$, ${}_p\eta^2 = .96$. The analysis of the pleasantness ratings also showed that the CS+ was rated as more unpleasant (*M* = -1.96, *SD* = 2.49) than the CS- (*M* = 1.44, *SD* = 2.45), $F(1, 39) = 33.08$, $p < .001$, $\eta_p^2 = .46$.

Forced-choice recognition task

To establish pre-attentive processing during the AAT, it is important to ascertain that during the subsequent forced-choice recognition test, participants did not exhibit above-chance recognition on the target trials (Murphy & Zajonc, 1993). On average, participants selected the correct image on 16.48 out of the 32 trials, which did not differ from chance, $t(39) = .82$, $p = 0.42$. Recognition was not above chance for either the 16 CS+ trials, *M* = 8.63, $t(39) = 1.16$, $p = 0.25$, or the 16 CS- trials, *M* = 7.85, $t(39) = -0.26$, $p = 0.80$. We additionally subjected the data to a formal signal detection analysis, by calculating a receiver operating characteristic (ROC) curve and examining the area under the ROC curve (*A'*). In such an analysis, participants can be classified as aware if their *A'* value is significantly different from .5. For the present experiment, the mean *A'* equaled .52, which indicates that participants were not able to detect the stimuli ($p = .13$). Based on both of these analyses, it appears that participants did not possess visual awareness of the stimuli as presented during the AAT.

AAT

Neither the main effect of Stimulus, nor the effect of Response reached significance (both *p*s > .40) in the analysis of the AAT, but a significant Stimulus × Response interaction was obtained, $F(1, 39) = 6.18$, $p = .02$, $\eta_p^2 = .14$ (Figure 1A). Surprisingly, the pattern was opposite to what was expected, with individuals having shorter RTs for approaching on CS+ trials and avoiding on CS- trials than for approaching on CS- trials and avoiding on CS+ trials. One participant in the sample had a much higher number of incorrect and long responses (n = 10) than the overall sample (2.5 *SD* higher than the sample mean). When this participant was removed from the analyses, the results remained the same. Thus, the data show that approach tendencies rather than avoidance tendencies were observed on the CS+ trials, relative to the CS- trials.

To exclude that the valence of the mask affected responding on the AAT, the mask should be rated as neutral. Indeed, self-reported pleasantness ratings of the mask suggested that it was rated as neutral ($M = .10$, $SD = 2.07$). Thus, any differences observed in responding to the CSs in the AAT can be assumed to result from pre-attentive processing of the CSs.

DPT

There was no main effect of Stimulus, $F(1, 39) = .18$, $p = .67$, $\eta_p^2 = .005$, which indicates that participants did not have an overall attentional bias for the threat stimulus. Further, no main effect of Movement was observed, $F(1, 39) = 1.58$, $p = .22$, $\eta_p^2 = .04$, which contradicts the idea that individuals would generally pay more attention to approaching than to withdrawing stimuli. However, the interaction between Stimulus and Movement did approach significance, $F(1, 39) = 3.91$, $p = .055$, $\eta_p^2 = .09$ (Figure 1B; the interaction becomes significant when mean RTs are used for the analyses, Stimulus × Movement interaction, $F(1, 39) = 6.91$, $p = .01$, η_p^2

= .15). Upon inspection of the data, it appears that individuals were faster at detecting probes replacing an approaching CS+ or a withdrawing CS- than probes replacing a withdrawing CS+ or an approaching CS-. The results are thus consistent with the threat imminence account.

Similarly to the AAT, one participant in the sample had a much higher number of incorrect and long responses (n = 10) than the overall sample (2.5 *SD* higher than the sample mean). The results of the DPT remained the same when the data of this participant were excluded from the analyses.

Discussion

In the present study, we set out to test two interrelated questions regarding the interaction between threat processing, distance change and the allocation of attention, i.e., whether pre-attentive processing of conditioned threat and safety signals can trigger avoidance tendencies and whether threat potential and distance change interact to guide the allocation of attention. First, we found that threat and safety signals were processed pre-attentively, but their effect upon conditioned avoidance tendencies was the opposite of what was hypothesized. Second, the data showed that increases in threat imminence (approaching of threat signals and withdrawing of safety signals) critically determine the allocation of attention.

This experiment is the first to show that attention is captured by increases of threat imminence and contributes to an emerging literature on the importance of threat imminence for shaping human defensive responses (Åhs et al., 2015; Löw et al., 2015; Löw et al., 2008; Mobbs et al., 2007, 2009). Our findings do not challenge previous findings that threat stimuli are preferentially attended to (Koster et al., 2005, 2004; Koster, Crombez, Verschuere, Van Damme, & Wiersema, 2006), because in those previous studies stimuli were presented without any distance change. When the stimuli remain static, it would be evolutionary sound to attend to threats; while when the threats are moving, attending to increases in threat imminence might be more beneficial. Further, we failed to observe a general preferential allocation of attention to objects moving toward the participant, which is at odds with findings from other tasks (Adams et al., 2006; Åhs et al., 2014; Bernstein et al., 1971; van Peer et al., 2009, Experiment 4). Notably, these tasks have measured psychophysiological or categorization (e.g., of movement) responses rather than attention. Future research can add simultaneous measurement of psychophysiology and attention to understand how they interact. One notable limitation of this experiment is that the dot-probe task was administered after the approach-avoidance task without counterbalancing of task order, which might explain the weak effects observed in the DPT. Last, but not least, van Peer and colleagues (2010) have shown that the instructions of the task (whether participants categorize valence or movement) might influence the findings. Here, participants received minimal instructions during the attentional bias task, which allowed the examination of spontaneous attentional bias.

Surprisingly, regarding pre-attentively triggered action tendencies, we observed precisely the opposite to what we expected and what has been observed for supraliminal threat cues (Krypotos et al., 2014). We found that individuals were faster to approach a mask replacing a subliminally presented threat signal and to avoid a mask replacing a subliminally presented safety signal than vice versa. Regardless of the direction of our findings, the fact that action tendencies were influenced by the subliminally presented stimuli suggests that they must have been processed pre-attentively and somehow primed motivated action. Thus, here we provide evidence that pre-attentively processed cues also elicit action tendencies.

To understand the direction of the effects in the approach-avoidance task, closer consideration of the paradigm used here may be helpful. During the AAT, participants had to respond to the orientation of the frame of the mask stimulus that replaced the conditioned stimuli. The appearance of the mask on each trial implied the removal of the target stimulus. Thus, on CS+ trials the mask effectively prevented the further presence of a threat stimulus, while on CS- trials the mask caused the offset of a safety stimulus. As such, pre-attentive processing of the target CS+ or CS- may have modulated the threat value of the mask on a given trial, in a way opposite to the threat value of the target preceding the mask (even if the mask itself was rated neutral at the end of the experiment). As a result, pre-attentive processing of the masked CS+ and CS- stimuli may have triggered action tendencies to the masking stimulus opposite to those elicited by supraliminal CS+ and CS- stimuli. Somewhat similar reversed priming effects have been reported in the affective priming literature. In several experiments, positively and negatively valenced primes have been shown to potentiate the processing of evaluatively incongruent targets (for a review, see Klauer, Teige-Mocigemba, & Spruyt, 2009), rather than of evaluatively congruent targets as it occurs more typically in affective priming experiments. While the exact mechanism underlying reversed affective priming effects remains poorly understood, those findings indicate that the reversed priming effect observed here is not without precedent. Nonetheless, our explanation for why it occurred here is post-hoc and awaits further corroboration.

An interesting topic for future research is the extent to which the capacity of subliminally presented CSs to elicit avoidance tendencies and other fear responses after conditioning is constrained to particular types of CSs (like the faces used here). Whereas the acquisition of conditioned fear responses, including avoidance tendencies, has been demonstrated using a variety of stimuli, including neutral geometrical shapes like triangles and circles (e.g., Koster et al., 2005; Krypotos et al., 2014; Lissek et al., 2008), studies on subliminal threat processing have typically used facial stimuli (Dimberg et al., 2000; Esteves et al., 1994; Mogg & Bradley, 1999; Morris et al., 1998; Olsson & Phelps, 2004) or compared fear-relevant and fear-irrelevant biological stimuli (e.g., snakes versus mushrooms) (Beaver et al., 2005; Flykt et al., 2007; Öhman & Soares, 1993). It thus remains a distinct possibility that only stimuli that have been evolutionary predisposed for threat learning (such as cues related to social interaction or immediate survival) can trigger pre-attentive processing and responding post conditioning (Mineka & Öhman, 2002).

In this experiment, we found support for the threat imminence account of defensive behaviour, by showing that individuals have an attentional bias towards increases of threat imminence. We also showed that subliminally presented threat and safety signals trigger action tendencies, the direction of which was possibly mediated by the effect of the subliminal targets on the threat value of the mask that replaced them in the approach-avoidance task. Collectively, these findings suggest that our cognitive system helps us not only focus on, but also deal with potential threat cues independent of conscious awareness.

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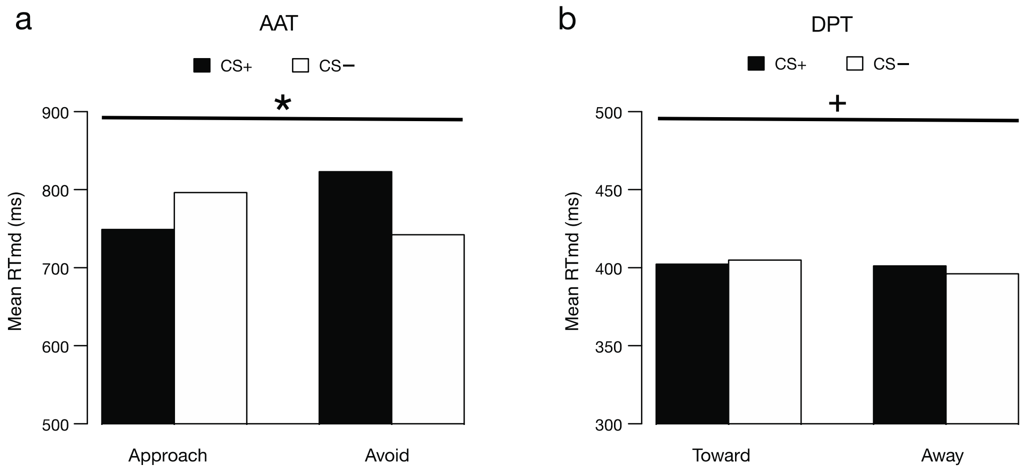
Figure 1 Mean median reaction times (RTmd) for approach and avoidance responses during the AAT (A) and for responses following approaching (toward) and withdrawing (away) CSs during the DPT (B)



Note: + p < .06 * p < .05